PATENT SPECIFICATION

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(19)

(54) SYSTEM FOR UNDERGROUND DISTRIBUTION OF ELECTRICAL POWER AND ELECTRICAL CABLE CONSTRUCTION FOR USE THEREIN

(71) We, REYNOLDS METALS COMPANY, a Corporation organised and existing under the laws of the State of Delaware, United States of America, of 6601 W. Broad Street, Richmond, Virginia 23261, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

Numerous systems are in use for underground distribution of alternating current (AC) electrical power and these systems utilize various types of cable constructions. For example, one type of cable construction in wide use in residential areas utilizes a central conductor, composed of one or more strands, which is insulated by a comparatively thick insulating sheath around which is supported an exposed concentric neutral conductor which may also be composed of one or more strands. One of the problems with such a cable construction is soil, galvanic, and AC corrosion of the neutral conductor, AC corrosion being caused by leakage currents from the neutral conductor.

Another problem with underground cable constructions of the character mentioned is that the systems used heretofore utilize tinned copper to make the neutral conductor and with the comparative short supply and high cost of copper, it has become necessary to utilize other materials, such as aluminium, for both the neutral conductor and the central conductor. However, it is important to protect cable constructions whether made totally or partially of copper or totally or partially of aluminium alloys against AC corrosion as well as soil and galvanic corrosion.

Regarding cathodic protection to prevent soil and galvanic corrosion, in the United States the National Association of Corrosion Engineers has established a recommended practice through a standard referred to as RP-01-69 that there should be a minimum negative polarization voltage shift of 150 milli volts for aluminium buried underground. Accordingly, one objective in an electrical cable construction for underground use is to provide cathodic protection that will produce a minimum negative polarization voltage shift of 150 mv.

According to the present invention, there is provided an underground AC electrical power cable construction having an uncovered neutral conductor and an integral sacrificial anode protecting the neutral conductor, the cable construction also comprising a central conductor within an insulating sheath the sacrificial anode being disposed radially outwardly of and against the insulating sheath and extending along substantially the full length thereof, the uncovered neutral conductor being disposed radially outwardly of and engaging the sacrificial anode at a plurality of points therealong, the sacrificial anode being anodic with respect to and protecting the neutral conductor underground against soil and galvanic corrosion as well as reducing AC corrosion of the neutral conductor by providing a substantial surface area for the dissipation of currents leaving the neutral conductor.

The invention also provides a system for distribution of AC power wherein such a cable construction extending underground connects a power source to a consumer sub-station.

The invention will now be described in more detail with the aid of examples illustrated in the accompanying drawings, in which:—

Fig. 1 is a schematic diagram of an A.C. electrical power distribution system using an underground electric cable.

Fig. 2 is a fragmentary view of a cable construction in accordance with the invention, with parts cut away,

Fig. 3 is a cross-section on the line 3-3 of Fig. 2,

Figs. 4, 5 and 7 are views similar to Fig. 3 showing other embodiments of the invention, and

Figs. 6 and 8 are views similar to Fig. 2 showing further embodiments of the invention.

Referring to Fig. 1, the electrical power distribution system shown comprises an A.C. power source 21 including a transformer 22 having primary connections 23 and secondary connections 24, electrical power being provided to the transformer 22 from a power generating station, not shown. The system 20 also comprises a consumer sub-station indicated at 25 which for simplicity of presentation is also shown as comprising a transformer 26 having primary connections 27 and secondary connections 30 and a plurality of three lines indicated at 31 which are connected to the secondary connections 30 at one end and tie in a consumer's installation at the opposite end thereof.

The system 20 of this example includes an electrical cable construction 33 embodying this invention and, reference is now made to FIGS. 2 and 3 of the drawings which illustrate details of the cable construction 33. The cable construction 33 comprises a central conductor 34, a comparatively thick insulating sheath 35 for the conductor, a sacrificial anode 36 which is supported by the insulating sheath and extends along essentially the full length of the sheath 35, and a current-carrying neutral conductor 37.

The neutral conductor 37 of this example is composed of a plurality of helically wound wires each of which is also designated by the reference numeral 37, for simplicity; even though it may be composed of a plurality of wires 37 the following description will often refer to the neutral conductor 37 in the singular. The neutral conductor 37 and indeed all wires thereof are supported concentrically around the insulator 35 and engage the sacrificial anode 36 at a large, indefinite number of points therealong.

The sacrificial anode 36 has been referred to as a multiple-purpose or dual-purpose anode and its dual purpose can be simply stated as being the protection of the neutral conductor 37 against soil and galvanic ocrrosion as well as against AC corrosion. The protection against soil and galvanic corrosion as well as against AC cor- the sacrificial anode 36 is in very close proximity to, i.e., against, the concentric neutral conductor 37 which is being protected. Similarly, because the anode 36 engages the neutral conductor at a very large number of points a substantially large surface area is provided for current which would otherwise leave the surface of the neutral conductor 37, thereby substantially reducing AC corrosion problems under normal service.

From FIG. 1 of the drawings, it will be seen that each end of the neutral conductor 37 which extends above ground level or out of the ground is connected to an associated transformer as shown at 40 in each instance while being connected to ground through the use of a grounding rod 41 and the grounding rod may be of any suitable construction or composition known in the art. It will also be appreciated that the central conductor extending from each end of the cable construction 33 is also connected to an associated transformer as illustrated by the reference numeral 42 in each instance.

The insulating sheath 35 may comprise a conductor shield 43 in the form of a comparatively thin sleeve arranged between the central conductor 34 and the thick, tubular, main insulator of the sheath 35. A typical wall thickness for a sleeve 43 used in a 1/0 American Wire Gauge (AWG) electrical cable construction is generally of the order of .030 inch as specified by the Association of Edison Illuminating Company (AEIC) and the Insulated Power Cable Engineers Association (IPCEA) — both of these well-known organizations having well-known specifications governing power cable. The sleeve 43 is preferably made of a semi-conducting cross-linked polyethylene with the semi-conducting characteristic being provided by carbon filling the polyethylene. The shield 43 serves as a smooth electrical surface in contact with the insulation provided by the main tubular insulator of the sheath 35.

The main insulator may be any suitable elastomeric insulating material known in the art such as a cross-linked polyethylene which is preferably applied in a continuous process by extrusion over the conductor 34 and the conductor shield 43. A typical cross-linked polyethylene insulator for a 1/0 AWG cable would have a wall thickness 44 which may range between .175-.345 inch, for example.

The sheath 35 may also include an outer tubular sleeve 45 which serves as a shield and outer covering for the main tubular insulator. The sleeve 45 is also made of a semi-conducting material such as carbon filled cross-linked polyethylene and for a 1/0 AWG cable construction the shield 45 may have a thickness which may range between .030-.070 inch.

The sacrificial anode 36 may be made of

any material which is anodic to the neutral conductor 37 and it will be appreciated that the neutral conductor may be made of copper, aluminium, or any suitable electrically conductive material. Based on cost and availability, the neutral conductor 37 is preferably made of an aluminium alloy whereby the sacrificial anode 36 is also made of an aluminium alloy anodic to the conductor 37. For example, with the usual alloys used to make a neutral conductor 37 an anode made of 7072 alloy has given satisfactory performance, (see Aluminum Standards and Data, The Aluminum Association, New York).

The sacrificial anode 36 may have any suitable configuration provided that initially it extends in a continuous manner along the entire length of the cable construction; the anode 36 may be made up of one or more strips, wires or other members. However, it will be appreciated that over the life of the cable, portions of the anode will be used up or "sacrificed" and the anode may not be continuous but be broken into a plurality of separated parts. Nevertheless, even though the initially continuous anode is thus separated into spaced parts, it is still very effective because it is contacted in an embracing manner at numerous points by the neutral conductor. In the cable construction 33 the anode 36 is shown as a single flat strip which is wound the entire length of the cable construction in a helical pattern.

The sacrificial anode 36 may be any suitable size or thickness; however, for a 1/0 AWG cable construction the anode 36 when in the form of a rectangular strip or ribbon of 7072 alloy may have a wall thickness ranging between .010 and .030 inch.

Having described the cable construction 33 in detail, reference is now made to FIGS. 4, 5, 6, and 7 which illustrate other exemplary embodiments of the cable construction of this invention. The cable constructions illustrated in FIGS. 4, 5, 6, and 7 are very similar to the cable construction 33; therefore, such cable constructions will be designated by the reference numerals 33A, 33B, 33C, and 33D respectively and representative parts of each cable construction which are similar to corresponding parts of cable construction 33 will be designated in the drawings by the same reference numeral as in the cable construction 33 (whether or not such components are mentioned in the specification) followed by an associated letter designation either A, B, C, or D and not described again in detail.

The cable construction 33A of FIG. 4 instead of having a sacrificial anode defined by a single helically wound metal rectangular strip or ribbon is in the form of an anode 36A defined by a plurality of three helically wrapped ribbons each designated by the reference numeral 47A and the ribbons 47A are helically wrapped or wound in the same direction along the full length of the insulator 35A and hence along the full length of the cable construction 33A.

The cable construction 33B of FIG. 5 has a sacrificial anode 36B comprised of a plurality of three cooperating metal wires 50B each of substantially circular cross-sectional configuration and each having substantially the same cross-sectional area. The wires 50B are helically wrapped along the full length of the insulator 35B and hence along the full length of the conductor 33B.

The cable construction 33C of FIG. 6 has a sacrificial anode 36C which is comprised of two helically wrapped metal members in the form of ribbons and each of such ribbons is designated by the same reference numeral 51C. The ribbons are helically wrapped concentrically around the insulator 35C with one of the ribbons 51C being wrapped in one direction or sense along the insulator 35C and as illustrated at 52C and the other of the 51C ribbons being wrapped against the first-named ribbon 51C in an opposite direction or sense as illustrated at 53C.

The cable construction 33D of FIG. 7 is composed of a pair of elongated members 54D each having an arcuate cross section including a concave surface 55D extending along the length thereof with the concave surface being particularly adapted to be cupped around the insulator 35D and in particular against the jacket 45D of such insulator 35D. The neutral conductor 37D is composed of a plurality of wires 37D which are wrapped concentrically around and against the elongated metal members 54D.

In this disclosure of the invention, reference has been made throughout to a neutral conductor which has been designated 37 or 37A-D in the various FIGS. of the drawings. In each instance the neutral conductor is shown composed of a plurality of components such as wires of circular cross section which are wound in a helical path around their associated insulator. However, it will be appreciated that the neutral conductor may be formed by a single component or member, if desired. Further, regardless of whether a single member or a plurality of members is involved in defining the neutral conductor in each instance each member involved may have any desired cross-sectional configuration.

In this disclosure of the invention the central conductor 34, 34A, 34B, 34C, and

34D has in each instance been shown as a conductor of solid cross section. However, it will be appreciated that each of such conductors may be a stranded conductor as illustrated in FIG. 8 of the drawings where the conductor is designated by the reference numeral 34.M The remainder of the cable construction 33 illustrated in FIG. 8 is identical to the cable construction.

It should also be emphasized that the central conductor of each cable construction may be tubular instead of solid or stranded. Further, each central conductor may be made of any suitable material such as aluminium, copper, or aluminium and copper, for example.

The cable construction of this invention may be made so that its central conductor, sacrificial anode, and neutral conductor are all made of suitable aluminium alloys, or these three basic components may be made of any other suitable metallic materials capable of being used together such as steel, copper, aluminium, and alloys thereof, provided the anode is anodic with respect to the neutral conductor. Further, the central conductor, sacrificial anode, and neutral conductor may each be made of one member or of a plurality of members, as desired.

In this disclosure, the neutral conductor has in each instance been shown a formed by a plurality of wires of solid cross section. However, it will also be appreciated that the neutral conductor, whether composed of one or more members, may also be made of stranded members or tubular members and such members may have any desired cross-sectional configuration.

The concentric neutral conductor whether made of one or more members may serve as a binding or fastening means or tape for embracing and holding the sacrificial anode (whether of one or more components) tightly against the sleeve 45 or tightly against the insulator 35 if no sleeve is used. This construction allows the cable construction 33, as well as constructions 33A-33D, to be easily installed without the need for special connections and procedures of the type required in prior art systems where separate discrete sacrificial anodes are employed.

WHAT WE CLAIM IS:—

1. An underground AC electrical power cable construction having an uncovered neutral conductor and an integral sacrificial anode protecting the neutral conductor, the cable construction also comprising a central conductor within an insulating sheath the sacrificial anode being disposed radially outwardly of and against the insulating sheath and extending along substantially the full length thereof, the uncovered neutral conductor being disposed radially outwardly of and engaging the sacrificial anode at a plurality of points therealong, the sacrificial anode being anodic with respect to and protecting the neutral conductor underground against soil and galvanic corrosion as well as reducing AC corrosion of the neutral conductor by providing a substantial surface area for the dissipation of currents leaving the neutral conductor.

2. A cable construction according to claim 1, in which the sacrificial anode is made of an aluminium alloy.

3. A cable construction according to claim 1, in which the said conductors and the sacrificial anode are each made of an aluminium alloy, the sacrificial anode alloy being anodic to the neutral conductor alloy.

4. A cable construction according to claim 1, 2 or 3, in which the sacrificial anode is a single helically wrapped ribbon.

5. A cable construction according to claim 1, 2 or 3, in which the sacrificial anode comprises a plurality of helically wrapped ribbons.

6. A cable construction according to claim 1, 2 or 3, in which the sacrificial anode comprises two ribbons helically wrapped around the insulating sheath, one of the ribbons being wrapped in one sense along the sheath and the other of the ribbons being wrapped concentrically around the first-named ribbon in the opposite sense.

7. A cable construction according to claim 1, 2 or 3, in which the sacrificial anode comprises at least one wire which is helically wrapped around the insulating sheath.

8. A cable construction according to claim 1, 2 or 3, in which the sacrificial anode comprises a plurality of wires which are helically wrapped around the insulating sheath, each of the wires having a circular cross section.

9. A cable construction according to claim 1, 2 or 3, in which the sacrificial anode comprises at least one substantially rectilinear member which is supported along the insulating sheath.

10. A cable construction according to claim 1, 2 or 3, in which the sacrificial anode comprises a pair of elongated members each having an arcuate cross section and a concave surface extending the length thereof, the concave surface being shaped to fit around the insulating sheath.

11. A cable construction according to any of claims 1 to 10, in which the insulating sheath comprises a main tubular insulator and a semi-conducting conductor shield in the form of a sleeve sandwiched between the central conduct r and the

main insulator.

12. A cable construction according to claim 11, wherein the said sleeve is made from a cross-linked polyethylene rendered semi-conducting and has a smooth electrical surface in contact with the main insulator.

13. A cable construction according to claim 11 or 12, which the insulating sheath further comprises a semi-conducting jacket around the main insulator.

14. A cable construction according to claim 13, wherein the said jacket is composed of polyethylene rendered semi-conducting.

15. A cable construction according to any preceding claim, wherein the neutral conductor serves as a fastening means embracing and holding the sacrificial anode tightly against the insulating sheath.

16. A cable construction according to any preceding claim, wherein the neutral conductor comprises a plurality of helically wound strands.

17. An underground AC electrical power cable substantially as hereinbefore described with reference to and as illustrated in Figs. 2 and 3 or Figs. 2 and 3 as modified by any of Figs. 4 to 8 of the accompanying drawings.

18. A system for the underground distribution of electrical power comprising, a power source, a consumer sub-station, and an electrical cable construction according to any preceding claim extending underground between the power source and the sub-station.

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Agents for the Applicants.

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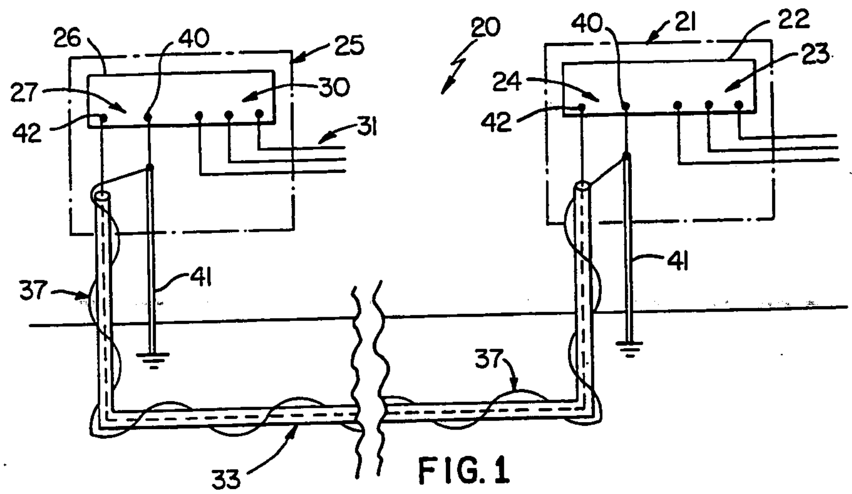

FIG. 1

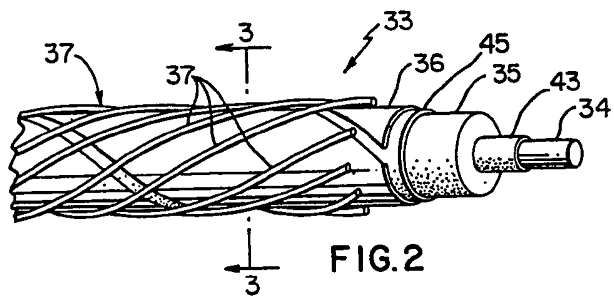

FIG. 2

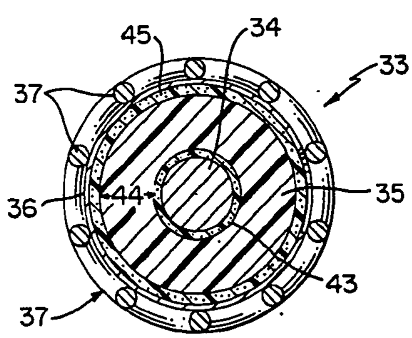

FIG. 3

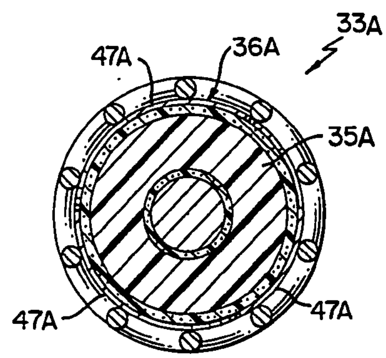

FIG. 4

1 502 938 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 2

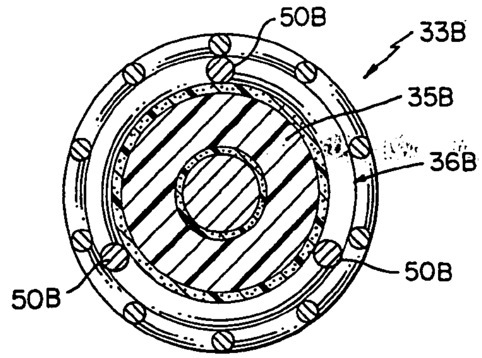

FIG.5

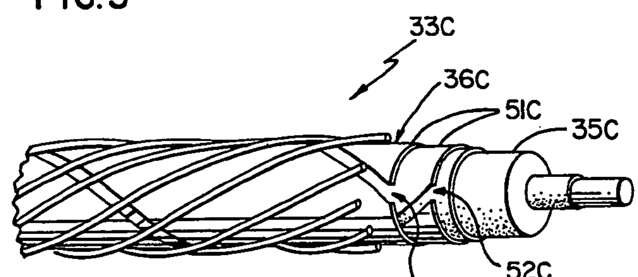

FIG.6

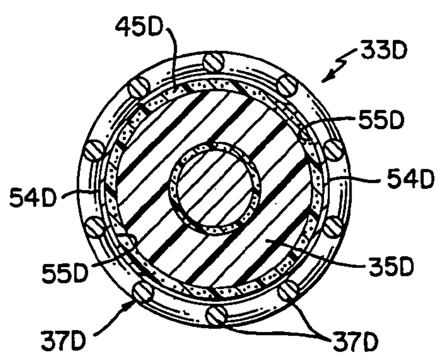

FIG.7

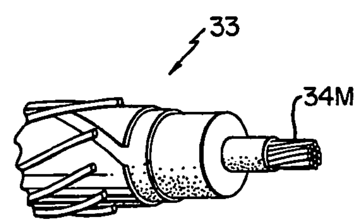

FIG.8